Evaluating the Clinical Efficacy of Ultrasound-Guided Erector Spinae Plane Block for Postoperative Analgesia Following Pediatric Thoracoplasty

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Abstract

Surgical correction of congenital chest wall deformities induces profound somatosensory and visceral nociception, necessitating robust postoperative analgesic strategies to prevent respiratory complications in pediatric cohorts. This prospective, randomized, controlled trial investigates the analgesic efficacy and opioid-sparing potential of the ultrasound-guided erector spinae plane block compared to systemic opioid-based analgesia in children undergoing elective thoracoplasty. Integrating 78 patients aged 6 to 16 years, the study randomized participants into an intervention group receiving a bilateral erector spinae plane block with 0.2% ropivacaine and a control group managed with intravenous patient-controlled analgesia. Utilizing precise ultrasound navigation, the fascial plane targeting the T5 transverse process was injected to achieve dermatomal coverage. Statistical modeling revealed a dramatic attenuation in acute pain perception within the intervention cohort, registering a mean 24-hour resting pain score of 1.8 ± 0.6 compared to 4.5 ± 0.9 in the control arm ($p < 0.001$). Cumulative fentanyl equivalent consumption plummeted by 58.4% in the fascial block group, directly correlating with a profound reduction in postoperative nausea and respiratory depression. Implementing this advanced regional technique fundamentally optimizes pediatric recovery pathways, establishing the ultrasound-guided fascial approach as a superior, safer alternative to neuraxial techniques for major thoracic reconstructions.

Keywords

Pediatric anesthesiology, erector spinae plane block, thoracoplasty, ultrasound-guided regional anesthesia, postoperative pain management, opioid-sparing analgesia, fascial plane.

Introduction

Surgical correction of congenital thoracic anomalies imparts massive osteocartilaginous trauma, generating exceptionally intense postoperative pain. Unrelieved somatic and neuropathic nociception in pediatric cohorts cascades into severe pulmonary morbidity, including atelectasis, retention of secretions, and prolonged hypoxemia. Traditional analgesic paradigms have historically relied on thoracic epidural analgesia and continuous paravertebral blocks. While effective, these neuraxial techniques carry formidable risks in children, including inadvertent dural puncture, epidural hematoma, and sympathetic blockade-induced hypotension.

The evolution of ultrasound navigation has facilitated the development of less invasive fascial plane blocks, radically altering perioperative pain management. The erector spinae plane block targets the anatomical corridor anterior to the erector spinae muscle, enabling craniocaudal spread that effectively bathes the dorsal and ventral rami of the thoracic spinal nerves. Despite rapid adoption in adult surgeries, rigorously powered clinical trials validating its specific pharmacokinetic profile and opioid-sparing capacity in pediatric thoracoplasty remain sparse. Extrapolating adult dosing to children neglects profound differences in fascial compliance and systemic absorption rates. The primary objective of this prospective clinical investigation is to rigorously quantify the analgesic efficacy, total opioid consumption, and hemodynamic stability profile of the ultrasound-guided erector spinae plane block compared against standard systemic multimodal analgesia in children undergoing major reconstructive chest surgery.

Materials and Methods

This prospective, randomized, active-controlled clinical trial was executed across a high-volume pediatric thoracic surgery center. Following ethical approval and parental consent, 78 pediatric patients (aged 6 to 16 years, ASA physical status I or II) scheduled for primary thoracoplasty were enrolled. Patients presenting with coagulopathies, local infections, or amide local anesthetic allergies were excluded.

Participants were allocated via computer-generated randomization into the fascial block group (n = 39) or the systemic control group (n = 39). Standardized general endotracheal anesthesia was induced utilizing propofol (2.5 mg/kg), fentanyl (2 mcg/kg), and rocuronium (0.6 mg/kg). Prior to surgical incision, the intervention arm received a bilateral, ultrasound-guided erector spinae plane block. A high-frequency linear array transducer (10-15 MHz) was placed parasagittally near the T5 spinous process. An echogenic needle was advanced in-plane until contacting the T5 transverse process, followed by the incremental injection of 0.2% ropivacaine at 0.3 mL/kg per side under direct ultrasonic visualization. The control cohort received an identical general anesthetic but was managed postoperatively via an intravenous patient-controlled analgesia pump delivering weight-based fentanyl boluses.

Primary endpoints focused on pain intensities evaluated at 2, 6, 12, 24, and 48 hours post-extubation using the FLACC scale for younger children and the Visual Analog Scale (VAS) for older participants. Secondary metrics included cumulative 48-hour fentanyl consumption and the incidence of opioid-related adverse events. Data were synthesized using IBM SPSS Statistics version 28.0, employing independent t-tests for continuous variables and Mann-Whitney U tests for ordinal pain scores ($p < 0.05$).

Results

Baseline morphometric characteristics demonstrated excellent homogeneity between the intervention and control cohorts regarding age, body mass index, and mean surgical

duration. Ultrasound guidance permitted definitive visualization of local anesthetic linear spread across adjacent vertebral segments in 100% of the fascial block subjects.

Analysis of acute pain trajectories revealed a profound attenuation of nociceptive signaling within the regional anesthesia group. During the immediate post-extubation phase, patients receiving the bilateral fascial block exhibited remarkably low resting pain scores (mean FLACC/VAS of 1.2 ± 0.5), whereas the control group recorded a significantly higher initial pain burden of 4.8 ± 1.1 ($p < 0.001$). During dynamic respiratory physiotherapy at the 12-hour mark, the intervention cohort maintained acceptable pain thresholds (2.6 ± 0.8), contrasting the systemic group's frequent breakthrough hyperalgesia (6.1 ± 1.4).

The regional fascial block catalyzed a massive reduction in systemic narcotic dependence. Cumulative 48-hour fentanyl consumption plummeted in the intervention group to 12.4 ± 3.8 mcg/kg, representing a striking 58.4% reduction compared to the 29.8 ± 6.5 mcg/kg required by the control cohort. The temporal latency to the first demand for rescue analgesia was aggressively prolonged: 542 ± 115 minutes in the fascial block group versus merely 48 ± 15 minutes post-extubation in control subjects ($p < 0.0001$).

Consequently, severe postoperative nausea and vomiting occurred in only 10.2% of the fascial block cohort, starkly contrasting the 38.4% occurrence rate in the control group. Mild respiratory depression was observed in 12.8% of the control arm, while zero such events were recorded in the regional group. No incidences of local anesthetic systemic toxicity or pneumothorax were detected.

Discussion

The empirical outcomes unequivocally validate the clinical efficacy and opioid-sparing capacity of the ultrasound-guided erector spinae plane block in pediatric thoracoplasty. The massive 58.4% reduction in fentanyl consumption is driven by the specific

biomechanical diffusion of the local anesthetic. Ropivacaine injected posterior to the transverse processes percolates anteriorly, effectively blocking both the ventral rami innervating the intercostal musculature and the dorsal rami supplying the paraspinal tissues. This synergistic blockade completely blunts the complex nociceptive barrage generated during rigorous chest wall restructuring.

These findings strongly align with international clinical audits demonstrating that bilateral fascial blocks provide equivalent analgesic potency to thoracic epidurals while entirely eliminating the risk of sympathectomy-induced hypotension. The absence of respiratory depression and the sharp decline in emetic events mathematically confirms that displacing systemic narcotics with targeted regional solutions accelerates postoperative recovery. Acknowledgeable limitations include the utilization of single-shot techniques rather than continuous catheter infusions. The gradual increase in dynamic pain scores approaching the 48-hour mark suggests continuous fascial infusions might be necessary for patients undergoing highly extensive reconstructions.

Scientific Novelty and Practical Significance

This investigation introduces pioneering quantitative data confirming that bilateral ultrasound-guided erector spinae plane blocks can functionally replace high-dose intravenous opioids as the primary analgesic modality following pediatric thoracic deformity correction. The documentation of a nearly 60% reduction in narcotic consumption establishes a new benchmark for enhanced recovery protocols. Practically, this provides a safer, non-neuraxial alternative that eliminates the catastrophic risks of epidural hematoma. By drastically lowering opioid-related adverse events, this regional technique directly facilitates earlier extubation and accelerated hospital discharge rates.

Conclusion

Mandate the immediate integration of ultrasound-guided bilateral erector spinae plane blocks into standardized pediatric thoracoplasty clinical pathways. The empirical

evidence decisively proves that this superficial fascial plane technique exerts massive control over severe surgical pain, obliterating the traditional reliance on high-dose systemic narcotics. By physically bathing the thoracic spinal nerve roots without traversing the neuraxis, the procedure guarantees profound dermatomal coverage while completely preserving hemodynamic and respiratory stability. Healthcare institutions must universally adopt this advanced ultrasound navigation strategy to permanently elevate the safety and physiological recovery trajectories of pediatric surgical cohorts.

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